A Preliminary Study of the Relationship Between Central Auditory Processing Disorder and Attention Deficit Disorder

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Fifteen boys aged six to ten who met the criteria for attention deficit disorder (ADD) were compared with ten boys who did not have ADD in a double-blind, placebo-controlled, single-crossover study of methylphenidate. To assess the degree of overlap between ADD and central auditory processing disorder (CAPD), all subjects were assessed on parent and teacher behavior rating scales, as well as a battery of CAPD tests at baseline and after three and six weeks of treatment. Twelve of the 15 subjects with ADD and none of the subjects without ADD met the criteria for CAPD. The subjects with ADD also responded to stimulant treatment on the measures of both ADD and CAPD. The overlap in the symptomatology of these disorders, the finding that the criteria for both disorders were met in 12 of 15 cases and the sensitivity of both ADD and CAPD measures to treatment with methylphenidate suggest that ADD and CAPD are closely related disorders. The implications of these results are three-fold. First, sustained attention is a critical feature of performance on CAPD tests and the current diagnostic criteria for CAPD make a clinical separation of the two disorders problematic. Second, stimulants appear to be a useful treatment for the symptoms of both ADD and CAPD. Third, CAPD tests may be a useful measure of ADD symptomatology and response to stimulants.

Key Words: children, attention deficit disorder, central auditory processing disorder, stimulants, diagnosis

INTRODUCTION

In recent years, a number of articles have appeared on central auditory processing disorders (CAPD). A recent bibliography from the American Speech-Language-Hearing Association (1988) lists more than 200 articles on CAPD. More than 30 of these articles deal with the assessment of central auditory function in children. A significant number of school-aged children have been diagnosed with CAPD using a battery of specialized audiometric tests, and is treated through environmental manipulation (Johnson 1982; Johnson et al 1982; Gascon et al 1986; Burd and Fisher 1986; Katz and Wilde 1985; Katz 1962; Keith 1981; Kushner et al 1982; Ludlow et al 1983; Lukas and Eschenhermir 1982; Nelson 1981; Pinheiro and Musiek 1985; Stublefeld and Young 1982; Willeford 1985; Willeford 1977). The disorder is reported to contribute significantly to academic and behavioral dysfunction among school-aged children (Katz and Wilde

1985; Katz 1962; Keith 1981; Kushner et al 1982; Stublefield and Young 1982; Willeford 1985) and is hypothesized to have a neurological substrate (Pinheiro and Musiek 1985).

Although the notion that children with learning disabilities have both auditory and visual perceptual problems is long-standing, there is as yet no conclusive evidence to support the hypothesis that visual or auditory impairments are a primary factor in learning disabilities (Johnson 1981; Kavale and Forness 1987; Arters and Jenkins 1977; Vellutino 1987; Rees 1981). The fact that up to 93% of special education teachers felt that matching students' modality strengths with appropriate instructional modalities was important may explain their enthusiasm for CAPD testing (Kavale and Forness 1987; Arters and Jenkins 1977).

The integrity of CAPD as a discreet diagnostic entity has been questioned by some researchers. Ludlow and associates (1983) found a weak relationship between CAPD and language disabilities in children, while others (Gascon et al 1986; Burd and Fisher 1986) have suggested that the diagnostic criteria for CAPD and attention deficit disorder (ADD) share many features which make the disorders clinically similar. The overlap between characteristics of children with CAPD — poor concentration, a tendency to be easily distracted, fidgeting, poor academic achievement — has been suggested as evidence of this similarity (Gascon et al 1986; Burd and Fisher 1986). These same clinical symptoms are essential criteria for a diagnosis of ADD in the DSM-III and for attention deficit-hyperactivity disorder (ADHD) in the DSM-III-R and are found on behavior rating scales for ADD (Swanson et al 1981; Ullman et al 1984). (ADD is now referred to as attention deficit-hyperactivity disorder in the DSM-III-R.) In addition, both ADD behavior rating scale scores and CAPD laboratory test scores have been found to be improved by stimulant medication (Gascon et al 1986).

There are several bases for criticizing the above-mentioned research (Gascon et al 1986; Burd and Fisher 1986). First, in the study of children meeting criteria for CAPD and ADD, treatment with methylphenidate was an open trial with raters who were not blind. Second, the study failed to include a comparison group of children without ADD. Finally, the CAPD tests used were narrowly focused.

In order to improve the information available to physicians who make diagnostic and treatment decisions with these patients, this study attempted to correct these methodological weaknesses. Two specific questions were posed: 1. Do CAPD test scores for children with ADD differ significantly from CAPD scores of children without ADD? 2. Does treatment with methylphenidate result in an improvement in diagnostic test scores for CAPD either separately or simultaneously?

METHODOLOGY

A double-blind, single-crossover, placebo-controlled study was conducted on a group of 15 subjects with ADD and a comparison group of ten age-matched subjects who did not have ADD. The study was approved by the Institutional Review Board of the University of North Dakota School of Medicine, and the parents' consent was obtained for the children in both the experimental and control groups.

Subject selection

Subjects were included if they were male, between the ages of six and ten, and if their full-scale IQ (FIQ) scores on the Wechsler Intelligence Scale for Children-Revised were 85 or above. Subjects were assigned to the experimental group if they received a clinical diagnosis of ADD from their pediatrician, met the DSM-III criteria for ADD on both the parent and teacher versions of the Swanson, Nolan and Pelham Checklist (SNAP) (Swanson et al 1981) and scored 15 points or more on the parent version of the Abbreviated Conners Rating Scale (ACRS) (Connors 1973). Subjects in the non-ADD, comparison group were included if they did not meet the criteria for ADD based on the parent and teacher behavior rating scales. Subjects were excluded from the study if they had seizures, cerebral palsy, learning disabilities, speech or language problems, vision or peripheral hearing problems, a thought disorder, abnormal auditory brainstem evoked potentials, or if they had received previous drug treatment for ADD.

Two problems often associated with diagnosing ADD are the changes in symptom clusters with age and variations in the expression of symptoms in different settings (Arnold et al 1981; Klein and Gittelman-Klein 1975). Therefore, in this study, the subjects were limited to the six- to ten-year age range and the children's behavior was sampled in the physician's office, at home and at school using different rating scales and measures of CAPD.

Experimental subjects

The experimental subjects were boys referred to their pediatricians presenting with complaints of inattention, impulsiveness and hyperactivity. As patients with ADD were found to meet the selection requirements, they were randomly assigned to one of two experimental groups.

Comparison subjects

The non-ADD comparison group was selected from a group of 40 boys in regular education classrooms who were identified by their teachers and principal as "average achievers." Nineteen boys were chosen at random from the list of 40 names. A letter was sent to their parents requesting that they participate in the study. Ten of the boys completed all phases of the data collection.

The ten boys in the non-ADD group were matched by age with boys in the two ADD groups, using the blocking procedure described above. None of these boys received medical intervention.

Assessment devices

Behavior rating scales

The standard instructions accompanying the ACRS, SNAP and ACTeRS were used in completing the forms. The ACRS and SNAP were scored by awarding no points if the attribute applied to the boy "not at all," one point for "just a little," two points for "pretty much," and three points for "very much."

A 15-point cutoff score for ADD was applied to the ACRS, as recommended (Sprague et al 1974). The parent and teacher versions of the SNAP were used to ensure that DSM-III criteria for inattention and impulsiveness were met. The subjects with ADD also met the DSM-III criteria for hyperactivity according to the parent version of this scale. A total score on the ACRS and the four subscale scores on each of the ACTeRS and the parent and teacher versions of the SNAP were the 13 dependent measures from the behavior rating scales.

CAPD battery

The CAPD battery consisted of five tests. The first was speech audiometry. This included speech reception threshold testing, speech discrimination in quiet and speech discrimination in noise, in which the signal (speech) was 5 decibels louder than the noise. The second was the Staggered Spondaic Word (SSW) test, developed by Katz, since standard speech audiometry did not adequately evaluate central auditory problems (Katz and Wilde 1985; Katz 1962). The SSW is a dichotic listening test in which each ear receives one stimulus individually and one stimulus simultaneously. Studies show that those who do not have CAPD and are between the ages of 11 and 60 make very few errors on the SSW, and that performance is not affected by sex, socioeconomic background or minor variations in intelligence. The SSW has been standardized with normal hearing subjects (including children as young as age five) and with patients who have surgically confirmed central nervous system lesions. The remaining instruments in the CAPD battery were subtests from the Willeford battery (Willeford 1985; Willeford 1977): the competing sentence Binaural Separation Test (BST), the Filtered Speech Test (FST) and the Rapidly Alternating Speech Test (RAST). In the BST, a sentence is presented to both ears simultaneously. The non-test ear sentence is presented 15 decibels louder than the test ear sentence, and the child is asked to repeat the sentence which is heard in the test ear. The FST consists of 50 words, filtered above 1,000 Hz at a rate of 16 decibels per octave, presented to each ear. The RAST alternates sounds in a sentence every 300 ms, and the child is asked to repeat the sentence. Scores for the right and left ears for speech discrimination with and without noise, the individual and simultaneous SSW, the BST, the FST and the total score for the RAST were the 13 dependent measures in the CAPD battery.

Drug treatment

All patients who met the inclusion criteria and who had given their consent to participate in the study were sent to a separate building, where they were assigned to groups by a table of random numbers known only to the pharmacist. The physician, audiologist, teachers and parents involved in behavior rating and the subjects themselves were blind to the treatment assignment.

Titration of the medication and placebo was carried out by the subject's pediatrician who interviewed the parents to assess the effectiveness of the treatment and to determine whether or not side-effects were occurring. The parents conferred with the child's teacher before their visits to the pediatrician. The dose was titrated up to a maximum of six tablets (either 5 mg methylphenidate tablets or a matching placebo) over the first three weeks of the experimental period. The dose of methylphenidate administered to the subjects in the experimental group averaged 0.30 mg/kg (SD = 0.057) and ranged from 0.20 to 0.38 mg/kg, at the time titrations were completed. This procedure resulted in a typical administration of 15 to 20 mg/day. After the first three-week experimental period and a weekend (minimum of 48 hours) without the drug or placebo, the experimental subjects switched treatments for the remaining three-week period. In short, one group received methylphenidate for three weeks followed by the placebo for three weeks; the opposite was true for the second group.

The subjects in the comparison group did not receive drugs or placebo. However, they were rated by their parents and teachers on admission to the study and at each three-week interval, using the same protocol as was used for the experimental group subjects.

Data analysis

The scores from the behavior rating scales were all converted to a common metric in a two-step process. First, those subscales normally scored in the direction of greater adjustment were re-scored in the direction of greater disturbance. Second, all subscale scores were expressed as a proportion of the maximum possible score. The scores from the CAPD battery were all expressed as a percentage of the total number of items on a test that were correct.

Multivariate analyses of variance (MANOVA) using planned orthogonal contrasts were used to answer two research questions concerning the relationship between ADD and CAPD. The first was whether or not the boys with ADD differed from the boys without ADD. This question was answered by comparing experimental and comparison subjects at baseline. The scores of the experimental group were expected to be higher on the behavior rating scales and lower on the CAPD battery than those of the comparison group.

The second research question — whether or not the CAPD test scores improved after treatment with methylphenidate —

was complicated by the possibility that treatment effects were confounded by placebo effects. To rule out this possibility, two orthogonal contrasts were selected, *a priori*, for testing. The first compared methylphenidate with the combined baseline and placebo observations (testing the treatment effect). The second compared baseline and placebo observations (testing the placebo effect). A methylphenidate treatment effect was expected in the first comparison, and no placebo effect was expected in the second.

Other potential confounding factors were practice and maturational effects. The possibility of improving ratings and test scores because of experience with assessment procedures and the passage of time alone was ruled out by using the comparison group data (Sprague et al 1974). Orthogonal contrasts were again selected *a priori*: one comparing baseline with combined three-week and six-week observations, and as the second orthogonal comparing three-week with six-week observations. Rejection of either null hypothesis was accepted as evidence of improvement with time. However, since the data were provided by non-ADD boys, the results must be interpreted with caution. It was expected that neither null hypothesis would be rejected.

RESULTS

The successful matching of experimental and comparison groups by age was confirmed using a t-test. The mean ages of the ADD subjects (mean = 104.5 months, SD = 11.02), and the subjects without ADD (mean = 98.8 months, SD = 16.78) were not found to be significantly different. The groups were not as closely matched in terms of their full-scale IQ scores. A t-test showed the comparison group to have a significantly higher mean FIQ (mean = 112.7, SD = 7.15) than the experimental group (mean = 100.5, SD = 10.43) ($t = 3.21$, $df = 23$, $p < 0.01$). Accordingly, the subject's IQ was entered as a covariate into subsequent analyses of between-group differences.

The degree of overlap between ADD and CAPD was assessed by determining the number of boys with and without ADD who met the pre-determined criteria for CAPD. The criterion for CAPD was being below age-level performance at baseline on at least three of the five CAPD test battery instruments (Gascon et al 1986). Twelve of the subjects with ADD and none of those without ADD met these criteria. The three subjects with ADD who did not meet these criteria scored below age-level on two of the five CAPD instruments.

Baseline analyses

CAPD battery

No differences between treatment and comparison groups were found on speech reception thresholds and speech discrimination. Because of their inability to discriminate between the subjects with and without ADD, the Staggered Spondaic Word test and the Filtered Speech Test were dropped from further analyses.

Significant group differences ($p < 0.01$) were found in MANOVAs performed on speech discrimination in noise and measures from the competing sentence BST and RAST. These tests were therefore selected for use in the balance of the study. The MANOVAs for speech discrimination in noise ($F = 12.99$, $df = 2,21$), BST ($F = 9.26$, $df = 2,21$) and RAST ($F = 7.98$, $df = 1,22$) corresponded to Wilks' Lambdas of 0.447, 0.531 and 0.734, respectively. Table 1 shows the speech discrimination in noise and the BST and RAST cell means. These MANOVAs were supported by the findings from univariate tests. The ANOVAs for right speech discrimination ($F = 26.65$, $df = 1,22$) and left speech discrimination ($F = 6.14$, $df = 1,22$) in noise, and right BST($F = 5.42$, $df = 1,22$) and left BST ($F = 19.04$, $df = 1,22$) were all significant beyond the 0.05 level.

Behavior rating scales

Significant group differences ($p < 0.01$) were also found in the MANOVAs performed on the ACTeRS, teacher version of the SNAP and parent rating scales (SNAP and

Table 1

Speech discrimination (in noise), BST and RAST measures by group, at baseline

Variable	n	Mean	SD
Speech (right)[2]			
• ADD	15	77.87	11.35
• non-ADD	10	99.20	2.53
• total	25	86.40	13.83
Speech (left)[1]			
• ADD	15	85.33	13.12
• non-ADD	10	98.40	5.06
• total	25	90.56	12.36
Competing sentence Binaural Separation Test (right)[1]			
• ADD	15	70.67	21.86
• non-ADD	10	95.00	7.07
• total	25	80.40	21.11
Competing sentence Binaural Separation Test (left)[2]			
• ADD	15	32.66	29.63
• non-ADD	10	88.00	12.29
• total	25	54.80	36.52
Rapidly Alternating Speech Test[2]			
• ADD	15	73.33	18.38
• non-ADD	10	99.00	3.16
• total	25	83.60	19.12

[1]univariate test significant at the 0.05 level
[2]univariate test significant at the 0.01 level

ACRS). The MANOVAs for the ACTeRS (F = 6.45, df = 4,19), teacher version of the SNAP (F = 5.94, df = 4,19) and parent rating scales (F = 27.33, df = 5,18) corresponded to Wilks' Lambdas of 0.424, 0.444 and 0.116, respectively. Univariate analyses of subscale scores were consistent with the multivariate findings of group differences for all except the social skills and oppositional subscales from the ACTeRS, and the peer interaction subscale from the teacher version of the SNAP. The boys with ADD had more disturbance than those without ADD at baseline, but this difference did not approach significance. These variables were dropped from further analysis.

Practice and maturational effects

CAPD battery

The improvement in speech discrimination and scores on the RAST from one session to the next could not be adequately tested because of a ceiling effect. That is, the non-ADD subjects obtained maximum scores (100% correct responses) on the speech discrimination test and RAST at three and six weeks. Practice and maturational effects were tested with the competing sentence BST, through the use of planned orthogonal contrasts. The baseline and combined three-week and six-week BST scores were not found to be significantly different (F = 2.27, df = 2,16), based on a Wilks' Lambda of 0.779. Similarly, the three-week and six-week BST scores were not found to be significantly different from each other (F = 0.621, df = 2,16), based on a Wilks' Lambda of 0.927. These findings suggest the BST scores for the non-ADD boys did not improve solely on the basis of prior experience with the test or with time.

Behavior rating scales

Practice and maturational effects were tested with the ACTeRS, teacher version of the SNAP and parent rating scales (SNAP and ACRS), through the use of planned orthogonal contrasts. The baseline and combined three-week and six-week ACTeRS (F = 0.56, df = 4,10), teacher version of the SNAP (F = 0.68, df = 4,10) and parent rating scale scores (F = 2.21, df = 5,14) were not found to be significantly different, based on Wilks' Lambdas of 0.818, 0.785, and 0.559, respectively. Similarly, the three-week and six-week ACTeRS (F = 0.13, df = 4,10), teacher version of the SNAP (F = 0.69, df = 4,10) and parent rating scale scores (F = 1.11, df = 5,14) were not found to be significantly different, based on Wilks' Lambdas of 0.949, 0.784, and 0.716. Thus, like the BST, the teacher and parent behavior rating scales, used with non-ADD boys, did not show evidence of change as a result of prior experience with rating or the passage of time.

Treatment effects

CAPD battery

Table 2 presents the cell means for the MANOVA evaluations of the drug and placebo effects with the boys who had ADD. The overall MANOVA testing the effect of drug condition was not found to be significant for speech discrimination in noise (F = 1.92, df = 4,52, Wilks' Lambda = 0.760). However, it was significant for the BST (F = 5.45, df = 4,54, Wilks' Lambda = 0.507) and the RAST (F = 2.97, df = 4,54, Wilks' Lambda = 0.672) at the 0.01 and 0.05 levels, respectively. The first set of planned orthogonal contrasts indicated differences between the methylphenidate and combined placebo and baseline conditions for speech discrimination in noise (F = 3.52, df = 2,26, Wilks' Lambda = 0.787), BST (F = 6.85, df = 2, 27, Wilks' Lambda = 0.663), and RAST (F = 9.41, df = 1,28, Wilks' Lambda = 0.748), that were significant

Table 2

Speech discrimination (in noise), BST and RAST measures for the group with ADD, by treatment condition

Variable	n	Mean	SD
Speech (right)			
• baseline	15	77.87	11.35
• placebo	15	79.60	14.74
• methylphenidate	14	89.29	11.22
• total	44	82.09	13.27
Speech (left)			
• baseline	15	85.33	13.13
• placebo	15	83.20	11.66
• methylphenidate	15	88.27	9.68
• total	45	85.60	11.50
Competing sentence Binaural Separation Test (right)			
• baseline	15	70.67	21.87
• placebo	15	79.33	26.85
• methylphenidate	15	90.00	13.63
• total	45	80.00	22.46
Competing sentence Binaural Separation Test (left)			
• baseline	15	32.67	29.63
• placebo	15	49.33	28.90
• methylphenidate	15	52.67	26.85
• total	45	44.89	29.20
Rapidly Alternating Speech Test			
• baseline	15	73.33	18.39
• placebo	15	77.33	29.63
• methylphenidate	15	90.67	10.33
• total	45	80.44	21.84

at the 0.05, 0.01 and 0.01 levels, respectively. Univariate analysis supported findings from the planned orthogonal contrasts between the methylphenidate and combined placebo and baseline condition for right speech discrimination in noise ($F = 5.86$, $df = 1,27$, $p < 0.05$), right BST ($F = 8.61$, $df = 1,28$, $p < 0.01$), and left BST ($F = 6.78$, $df = 1,28$, $p < 0.01$), but not left speech discrimination in noise. The second set of contrasts between baseline and placebo conditions were not found to be significant for speech discrimination in noise ($F = 0.53$, $df = 2,26$, Wilks' Lambda = 0.961), and RAST scores ($F = 0.48$, $df = 1,28$, Wilks' Lambda = 0.983). However, the differences between baseline and placebo conditions were found to be significant for BST ($F = 5.70$, $df = 2, 27$, Wilks' Lambda = 0.703) at the 0.01 level.

Univariate analysis revealed the left BST ($F = 10.38$, $df = 1,28$, $p < 0.01$) was the source of this significant difference. These findings suggest all three CAPD scores improved when the boys with ADD were treated with methylphenidate, except that there was also improvement in the left BST scores when the boys were treated with a placebo.

Behavior rating scales

The overall MANOVAs testing the effect of drug condition on ACTeRS ($F = 2.79$, $df = 4,54$, Wilks' Lambda = 0.687), teacher version of the SNAP ($F = 3.38$, $df = 6,52$, Wilks' Lambda = 0.517), and parent rating scale scores ($F = 2.61$, $df = 10, 48$, Wilks' Lambda = 0.420) were all found to be significant beyond the 0.05 level. The first set of planned orthogonal contrasts with behavior rating scale data indicated differences between the methylphenidate, and combined placebo and baseline conditions for the ACTeRS ($F = 4.37$, $df = 2,27$, Wilks' Lambda = 0.755), teacher version of the SNAP ($F = 6.44$, $df = 3,26$, Wilks' Lambda = 0.574), and parent rating scale scores ($F = 5.99$, $df = 5,24$, Wilks' Lambda = 0.445) at the 0.05, 0.01 and 0.01 levels, respectively. The findings from the planned orthogonal contrast between the methylphenidate and combined placebo and baseline conditions were consistent with univariate analysis of the remaining ACTeRS subscale scores (attention and hyperactivity), the inattention subscale score from the teacher version of the SNAP, and all of the parent rating subscale scores. The second set of contrasts, between baseline and placebo conditions for ACTeRS ($F = 1.55$, $df = 2,27$, Wilks' Lambda = 0.897), teacher version of the SNAP ($F = 1.51$, $df = 3,26$, Wilks' Lambda = 0.852) and parent rating scale scores ($F = 0.48$, $df = 5,24$, Wilks' Lambda = 0.909) were not significant. The social skills and oppositional subscales of the ACTeRS, and the peer interaction subscale of the teacher version of the SNAP were not included in these analyses, since they failed to differentiate between the groups with and without ADD in the baseline condition.

DISCUSSION

The subjects in the experimental group were selected from children referred to their pediatricians for evaluation of academic and behavior problems. They were included in the study if they had been given a DSM-III diagnosis of ADD by their pediatrician and met the DSM-III criteria for ADD on the SNAP used by the parents and teachers. These patients would also meet the criteria for ADHD in the DSM-III-R. The subjects also met the DSM-III criteria for hyperactivity on the parent version of the SNAP and did not differ from the non-ADD subjects on subscales from the ACTeRS (social skills, oppositional) and teacher version of the SNAP (peer interaction).

All 15 of the subjects with ADD were found to have some degree of central auditory processing dysfunction and did not score as well as the subjects without ADD on three sets of ADD behavior rating scales and three components of the CAPD test battery. Thirteen of the subjects with ADD had severe enough problems with central auditory processing to meet criteria for CAPD (Gascon et al 1986). The extensive overlap between ADD and CAPD has been reported by others using some of the above measures as well as more sophisticated measures of CAPD (Keith et al 1989). In that study, children referred for CAPD testing were separated correctly into an ADD group and a non-ADD group, 64% and 57% of the time, respectively, based on CAPD results (Keith et al 1989). The authors also clearly demonstrated that children with ADD have lower CAPD scores than children without ADD.

The outcome of this double blind, placebo-controlled trial of methylphenidate contributes to the growing amount of evidence suggesting a close relationship between ADD and CAPD. Evidence of a relationship is further strengthened by a failure to detect changes on any of the dependent measures in the non-ADD comparison group resulting from prior experience with the assessment tools or the passage of time. In contrast, all the subjects' scores on the three sets of behavior ratings and CAPD improved while the ADD boys were treated with methylphenidate, although improvement also occurred on the left competing sentence (BST) when the treatment was a placebo.

Study limitations

These conclusions should not be generalized to results obtained with measures other than the three behavior rating scales and the three components of the CAPD test battery used in this study. The sample is small ($n = 15$). While this was a crossover trial, the untreated control group was selected on the basis of normal academic achievement and a lack of known behavior problems. As a result, they would not be expected to show evidence of CAPD. This may affect the strength of the conclusions of this study. The stimulant treatment periods were brief, and the results may not have been maintained at the same level if the study had been conducted over a longer period.

Children with learning disabilities and normal children may also have a positive response to treatment with methylphenidate, based on questionnaires similar to those used in this study (Shaywitz and Shaywitz 1988). The failure of the SSW and the FST to discriminate between groups may be the result of the insufficient power of the sample. Alternatively, the two subtests may simply not be able to discriminate between children with and without ADD.

It is likely that some children have central auditory deficits without attentional deficits. However, the CAPD tests used in this study may not be able to discriminate between children with both CAPD and ADD and those with CAPD only. As a result, for a diagnosis of CAPD, it is necessary to rule out a diagnosis of ADD by some other means.

It would be useful to replicate these findings with two epidemiologically independent samples of children who had been diagnosed with either ADD or CAPD. However, two studies have found that children with CAPD frequently meet criteria for ADD and that ADD can be identified by CAPD testing (Gascon et al 1986; Burd and Fisher 1986; Keith et al 1989). Such a trial should allow for the determination of the sensitivity and specificity of the measures used in this study. The presence of ADD in children referred for CAPD evaluation and vice versa would raise questions about the usefulness of CAPD as it is currently defined and diagnosed in children.

Future studies should compare the efficacy of CAPD tests, ADD rating scales and visual continuous performance tasks to monitor the response of both pharmacological and behavioral intervention with children who have been diagnosed with ADD. They should also determine whether or not CAPD testing is a clinically useful tool for titrating pharmacological and behavioral interventions for children with ADD. Studies comparing boys and girls are also important. The Screening Test for Auditory Processing Disorders is administered using a portable stereo cassette player and headphones (Keith et al 1989). It may therefore be useful for diagnosing ADD and for monitoring of the response to stimulants of children with ADD in clinical settings.

Finally, considerable study needs to be focused on the concept of the CAPD disorder as a discreet diagnostic entity and on refinement of the diagnostic methodology used to define this disorder in clinical settings before assessment and diagnosis with current CAPD tests are used for populations other than children (Jerger et al 1990).

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